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(54) Balanced battery charger

(57) A balanced battery charger maintains a balanced charge upon a plurality of battery cells which are connected in series with one another. The balanced battery changer has a monitoring circuit for determining when an imbalance between the charge upon the battery cells occurs and a charging/discharging circuit for selectively charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells. Balancing the charge upon the battery cells substantially enhances the life thereof.

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Description

Field of the Invention

The present invention relates generally to battery charging circuits and more particularly to a balanced battery charger for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another, so as to enhance the useful life thereof.

Background of the Invention

Battery chargers for maintaining a desired charge upon one or more batteries are well known. Such battery chargers are frequently utilized to maintain a charge upon a plurality of seriesed batteries by applying a voltage thereacross. The seriesed batteries are thereby charged according to well known principles.

However, it is also well known that such a contemporary battery charger does not mitigate the formation of an imbalanced charge upon the seriesed batteries and that such an imbalance substantially reduces the useful life of the batteries. As those skilled in the art will appreciate, such imbalances commonly occur due to inherent differences in individual cell construction, such as differences in the internal resistance of each cell.

Thus, it is beneficial to provide a battery charging circuit for charging seriesed batteries which prevents the formation of an imbalance between the batteries being charged, so as to enhance the useful life thereof.

Summary of the Invention

The present invention specifically addresses and alleviates the above-mentioned deficiencies associated with the prior art. More particularly, the present invention comprises a balanced battery charger for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another. The balanced battery charger more particularly comprises a monitoring circuit for determining when an imbalance between the charge upon the battery cells occurs, and a charging/discharging circuit for charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells. Balancing the charge upon the battery cells substantially enhances the life thereof.

The monitoring circuit is preferably configured to monitor a selected battery cell's charged relative to a charge of a plurality of the battery cells. According to the preferred embodiment of the present invention, the monitoring circuit is configured to monitor a selected battery cell's charge relative to the charge of all of the battery cells.

The monitoring circuit preferably comprises a voltage divider for providing a reference signal representative of a desired charge on selected battery cells and a tap for providing a battery cell charge signal representative of an actual charge on the selected batter cell(s). A comparitor compares the reference signal to the cell charge signal and effects control of the charging/discharging circuit.

Thus, the monitoring circuit preferably comprises a voltage divider for providing a reference signal representative of a desired charge on selected battery cells, a tap for providing a battery cell charge signal representative of the actual charge on the selected battery signal, and a comparitor for comparing the referenced signal to the cell charged signal and for effecting control of the charging/discharging circuit. The charging/discharging circuit preferably comprises a micro controller having a tri-state output, the tri-state output facilitating charging, discharging, and maintenance of the charge upon the selected battery cell(s).

According to the preferred embodiment of the present invention, the monitoring circuit and the charging/discharging circuit are at least partially defined by a micro controller, preferably via a multiplexed analog input and digital output of the micro controller. More particularly, the monitoring circuit and the charging/discharging circuit are at least partially defined by a PIC16C74 micro controller, with the monitoring circuit being defined by an analog input circuit and a multiplexed analog input and digital output circuit of the PIC16C74, and the charging/discharging circuit being defined by the multiplexed analog input and digital output circuit of the PIC16C74 micro controller.

Thus, according to the preferred embodiment of the present invention, the balanced battery charger comprises a charging/discharging circuit which is configured to charge at least one selected battery cell when the selected battery cell(s) have a lower charge than other battery cells, discharge at least one selected battery cell when the selected battery cell(s) have a higher charge than other battery cells, and maintain a charge upon at least one selected battery cell when the selected battery cell(s) have substantially the same charge as the other battery cells.

These, as well as other advantages of the present invention will be more apparent from the following description and drawings. It is understood that changes in the specific structure shown and described may be made within the scope of the claims without departing from the spirit of the invention.

Brief Description of the Drawings

Figure 1 is a schematic of the preferred embodiment of the present invention; and

Figure 2 is a flow chart showing the operation of the preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiment

The detailed description set forth below in connec-

tion with the appended drawings is intended as description of the presently preferred embodiment of the invention and is not intended to represent the only form in which the present invention may be constructed or utilized. The description sets forth the functions and the sequence of steps for constructing and operating the invention in connection with the illustrated embodiment. It is to be understood, however, that the same or equivalent functions and sequences may be accomplished by different embodiments that are also intended to be encompassed within the spirit and scope of the invention.

Referring now to Figure 1, the balanced battery charger of the present invention generally comprises a plurality of battery cells 10 for which it is desired to maintain a balanced charge thereupon, and a micro controller 12 for facilitating the maintenance of a balanced charge upon the plurality of battery cells 10.

More particularly, the plurality of battery cells 10 comprise a first battery cell 14 and a second battery cell 16 for which it is desirable to maintain a generally uniform charge thereupon so as to enhance the useful life thereof. Although only two battery cells 14, 16 are described and shown in accordance with the preferred embodiment of the present invention, those skilled in the art will appreciate that various different plural numbers of such battery cells may be utilized according to the present invention. Indeed, each individual cell 14, 16 of the present invention may actually comprise a plurality of cells connected either in series or parallel or any combination thereof, as desired. Thus, the balance battery charger of the present invention may be utilized to maintain a balanced or generally uniform charge upon either a plurality of single cells or various different configurations or groups of cells, as desired.

According to the preferred embodiment of the present invention, a current source 18 provides charging current to the plurality of battery cells 10 when first switch 20 is closed, thus completing circuit to the plurality of battery cells 10. The first switch 20 is controlled via input 22 thereto which is communicated from digital output 24 of the micro controller 12.

The monitoring circuit generally comprises a voltage divider comprised of first 26 and second 28 resistors. The number and values of resistors in the voltage divider is dependant upon the number of battery cells, e.g., 14, 16, in the plurality of battery cells 10. As those skilled in the art will appreciate, the values of the resistors of the voltage divider must be selected such that the voltage measured intermediate two resistors thereof is representative of the desired charge upon the first battery cell 14.

The actual charge upon the first battery cell 14 is measured, through second switch 32 and current limiting resistor 34, at the multiplexed analog input and digital output 36 of the micro controller 12. The micro controller 12 then compares the actual value of the charge upon the first battery cell 14 which is received at the multiplexed analog input and digital output 36 with the desired charge for the first battery cell 14 as measured at the analog input 30 and generated by the voltage divider comprised of resistors 26 and 28. If the actual charge upon the first battery cell 14, as measured at the multiplexed analog input and digital output 36 is higher than the desired charge, as measured at the analog input 30, then multiplexed analog input and digital output 36 is set to a low state so as to function as a drain and thereby discharge the first battery cell 14. In a like manner, when the charge upon the first battery cell 14 determined to be at a lower than desired state when compared with the desired charge at the analog input 30, then the multiplexed analog input and digital output 36 is set at a high state, so as to function as a source and thereby effect charging of the first battery cell 14. When the charge upon the first battery cell 14 is determined to be within tolerance, i.e., generally the same as the charge upon the second battery cell 16 such that a balanced condition exists, then the multiplexed analog input and digital output 36 of the micro controller 12 is set at its zero level so as to effect maintenance of the charge upon the first battery cell 14, i.e., no charging or discharging of the first battery cell 14 occurs.

As those skilled in the art will appreciate, when only two battery cells 14, 16 are utilized, then the first 26 and second 28 resistors of the voltage divider will have equal values, e.g., 100 kohms, for example, so as to provide a signal representative of the desired value of the battery charge of the first battery 14 to the analog input 30 of the micro controller 12.

The battery charge enable signal is provided by the digital output 24 of the micro controller 12 so as to effect actuation or closing of the first switch 20 and the second switch 32. The first switch 20 is closed so as to enable charging of the plurality of battery cells 10. The second switch 32 is closed so as to effect charging of the first battery cell 14 or discharging of the first battery cell 14, as determined by the state of the multiplexed analog input and digital output 36 of the micro controller 12. The second switch 32 also prevents current leakage from the plurality of battery cells 10 through the microprocessor, when the microprocessor is unpowered. However, as those skilled in the art will appreciate, the second switch 32 may not be required if the microprocessor itself prevents such leakage.

Voltage regulator 38 regulates the voltage output of the plurality of battery cells 10 to a desired value, such as +5 volts, which may be utilized to effect the powering of desired electrical devices, including the micro controller 12, if desired.

Referring now to Figure 2, in operation the voltage is measured 100 at the top of the two cells in series and is resistively divided in half to determine the desired voltage for first battery cell 14. The voltage is also measured 102 at the midpoint between the cells so as to effect measurement of the actual voltage upon the first

battery cell 14.

If the top measurement, i.e., the desired voltage for the first battery cell 14 as input to the analog input 30 minus the mid measurement, i.e., the actual measurement of the voltage upon the first battery cell 14 as measured at the multiplexed analog input and digital output 36, is greater than a predetermined limit 104, then the multiplexed analog input and digital output 36 is set 108 to a logic 1 so as to function as a current source to effect charging of the first battery cell 14. Otherwise, if the mid measurement minus the top measurement is greater than the preset limit, then the multiplexed analog input and digital output 36 is set 110 to logic 0 so as to function as a drain or sink so as to effect discharging of the first battery cell 14.

Otherwise, the multiplexed analog input and digital output 36 of the micro controller 12 is set 112 to the tri-state midpoint so as to effect maintenance of the charge upon the first battery cell 14, i.e., no substantial charging or discharging occurs.

According to the preferred embodiment of the present invention, the process repeats 114 after approximately a one second delay, so as to effect repeated and continual monitoring of the balance of the charge upon the plurality of battery cells 10 and so as to effect the generally constant maintenance of a desired balanced condition thereof.

Also, although the PIC16C74 micro controller 12 utilizes a multiplexed analog input and digital output 36, those skilled in the art will appreciate that various other microprocessors may be utilized which provide for analog input and digital output on separate pins thereof.

It is understood that the exemplary balanced battery charger described herein and shown in the drawings represents only a presently preferred embodiment of the invention. Indeed, various modifications and additions may be made to such embodiment without departing from the spirit and scope of the invention. For example, the limits for steps 104 and 106 of Figure 2 may be different from one another, as desired. Also, various different types and numbers of battery cells may be utilized. Further, as those skilled in the art will appreciate, various different microprocessors may be utilized. Indeed, a custom micro controller may be utilized.

Thus, these and other modifications and additions may be obvious to those skilled in the art and may be implemented to adapt the present invention for use in a variety of different applications.

Claims

1. A balanced battery charger for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another, the balanced battery charger comprising:

   a) a monitoring circuit for determining when an imbalance between the charges upon the battery cells occurs; and

   b) a charging/discharging circuit for selectively charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells;

   c) wherein balancing the charge upon the battery cells substantially enhances a life thereof.

2. The balanced battery charger as recited in Claim 1, wherein the monitoring circuit is configured to monitor a selected battery cell's charge relative to a charge of a plurality of the battery cells.

3. The balanced battery charger as recited in Claim 1, wherein the monitoring circuit monitors a selected battery cell's charge relative to a charge of all of the battery cells.

4. The balanced battery charger as recited in Claim 1, wherein the monitoring circuit comprises:

   a) a voltage divider for providing a reference signal representative of a desired charge upon selected battery cell(s);

   b) a tap for providing a cell charge signal representative of an actual charge on the selected battery cell(s);

   c) a comparitor for comparing the reference signal to the cell charge signal and for effecting control of the charging/discharging circuit.

5. The balanced battery charger as recited in Claim 1, wherein:

   a) the monitoring circuit comprises a voltage divider for providing a reference signal representative of a desired charge on selected battery cells, a tap for providing a cell charge signal representative of an actual charge on the selected battery cell(s), and a comparitor for comparing the reference signal to the cell charge signal and for effecting control of the charging/discharging circuit; and

   b) the charging/discharging circuit comprises a micro controller having a tri-state output, the tri-state output facilitating charging, discharging, and maintenance of the charge upon the selected battery cell(s).

6. The balanced battery charger as recited in Claim 1, wherein the monitoring circuit and the charging/discharging circuit are at least partially defined by a micro controller.

7. The balanced battery charger as recited in Claim 1, wherein the charging/discharging is at least partially defined by a multiplexed analog input and digital output of a micro controller.

8. The balanced battery charger as recited in Claim 1, wherein the monitoring circuit and the charging/discharging circuit are at least partially defined by a PIC16C74 micro controller, with the monitoring circuit being defined by an analog input circuit and a multiplexed analog input and digital output circuit of the PIC16C74, and the charging/discharging circuit being defined by a multiplexed analog input and digital output circuit of the PIC16C74 micro controller.

9. The balanced battery charger as recited in Claim 1, wherein the charging/discharging circuit is configured to:

a) charge at least one selected battery cell when the selected battery cell(s) have a lower charge than other battery cells;
b) discharge at least one selected battery cell when the selected battery cell(s) have a higher charge than other battery cells; and
c) maintain a charge upon at least one selected battery cell when the selected battery cell(s) have substantially the same charge as other battery cells.

10. A method for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another, the method comprising the steps of:

a) determining when an imbalance between the charges upon the battery cells occurs; and
b) selectively charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells;
c) wherein balancing the charge upon the battery cells substantially enhances a life thereof.

11. The method as recited in Claim 10, wherein the step of determining when an imbalance between the charge upon the battery cells occurs comprises monitoring a selected battery cell's charge relative to a charge of a plurality of the battery cells.

12. The method as recited in Claim 10, wherein the step of determining when an imbalance between the charge upon the battery cells occurs comprises monitoring a selected battery cell's charge relative to a charge of all of the battery cells.

13. The method as recited in Claim 10, wherein the step of determining when an imbalance between the charge upon the battery cells occurs comprises the steps of:

a) providing a reference signal representative of a desired charge upon selected battery cell(s);
b) providing a cell charge signal representative of an actual charge upon the selected battery cell(s);
c) comparing the reference signal to the cell charge signal and utilizing the result to effect control of the charging/discharging circuit.

14. The method as recited in Claim 10, wherein the step of determining when an imbalance between the charge upon the battery cells occurs comprises:

a) providing a reference signal representative of a desired charge on selected battery cells via a voltage divider;
b) providing a cell charge signal representative of an actual charge on the selected battery cell(s) via a tap;
c) comparing the reference signal to the cell charge signal and then utilizing the result to effect control of the charging/discharging circuit; and
d) selectively charging, discharging and maintaining the charge upon the selected battery cell(s) via micro controller having a tri-state output.

15. The method as recited in Claim 10, wherein the step of determining when an imbalance between the charge upon the battery cells occurs and the step of selectively charging and discharging at least a selected one of the battery cells comprises determining when an imbalance between the charge upon the battery cells occurs and selectively charging and discharging at least a selected one of the battery cells via a micro controller.

16. The method as recited in Claim 10, wherein the step of selectively charging and discharging at least a selective one of the battery cells comprises selectively charging and discharging at least a selected one of the battery cells utilizing a multiplexed analog input and digital output of a micro controller.

17. The method as recited in Claim 10, wherein the steps of determining when an imbalance between the charge upon the battery cells occurs and selectively charging and discharging at least a selected one of the battery cells comprise determining when an imbalance between the charge upon the battery cells occurs and selectively charging and discharging at least a selected one of the battery cells via a PIC16C74 micro controller, wherein the monitoring circuit is at least partially defined by an analog input circuit and a multiplexed analog input and digital output circuit of the PIC16C74, and a charging/discharging circuit is defined by a multiplexed analog

input and digital output circuit of the PIC16C74 micro controller.

18. The method as recited in Claim 10, wherein the step of selectively charging and discharging at least a selected one of the battery cells comprises the steps of:

a) charging at least one selected battery cell when the selected battery cell(s) have a lower charge than other battery cells;
b) discharging at least one selected battery cell when the selected battery cell(s) have a higher charge than other battery cells; and
c) maintaining a charge upon at least one selected battery cell when the selected battery cell(s) have substantially the same charge as other battery cells.

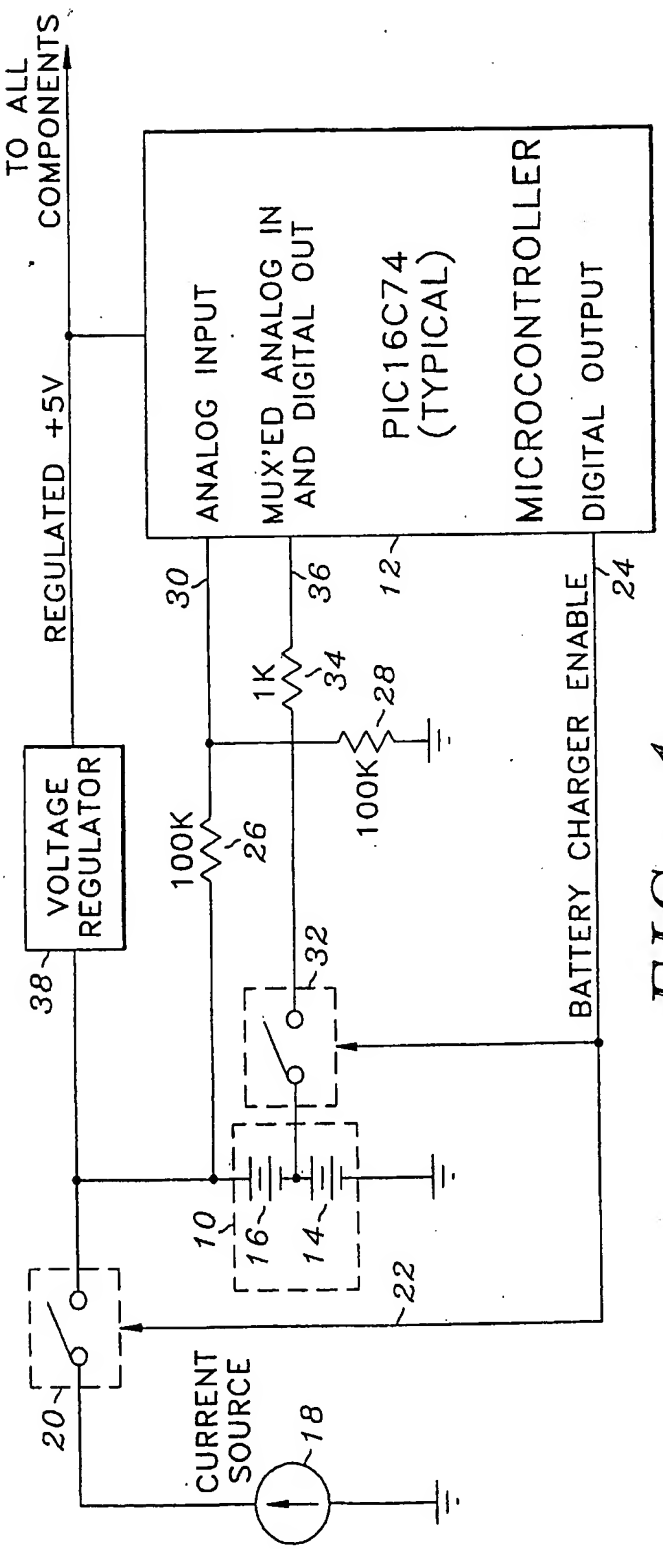
TO ALL COMPONENTS
REGULATED +5V
VOLTAGE REGULATOR
38
MICROCONTROLLER
PIC16C74 (TYPICAL)
ANALOG INPUT
MUX'ED ANALOG IN AND DIGITAL OUT
DIGITAL OUTPUT
12
30
36
24
1K
34
28
100K
26
100K
32
BATTERY CHARGER ENABLE
10
16
14
22
20
CURRENT SOURCE
18

FIG. 1

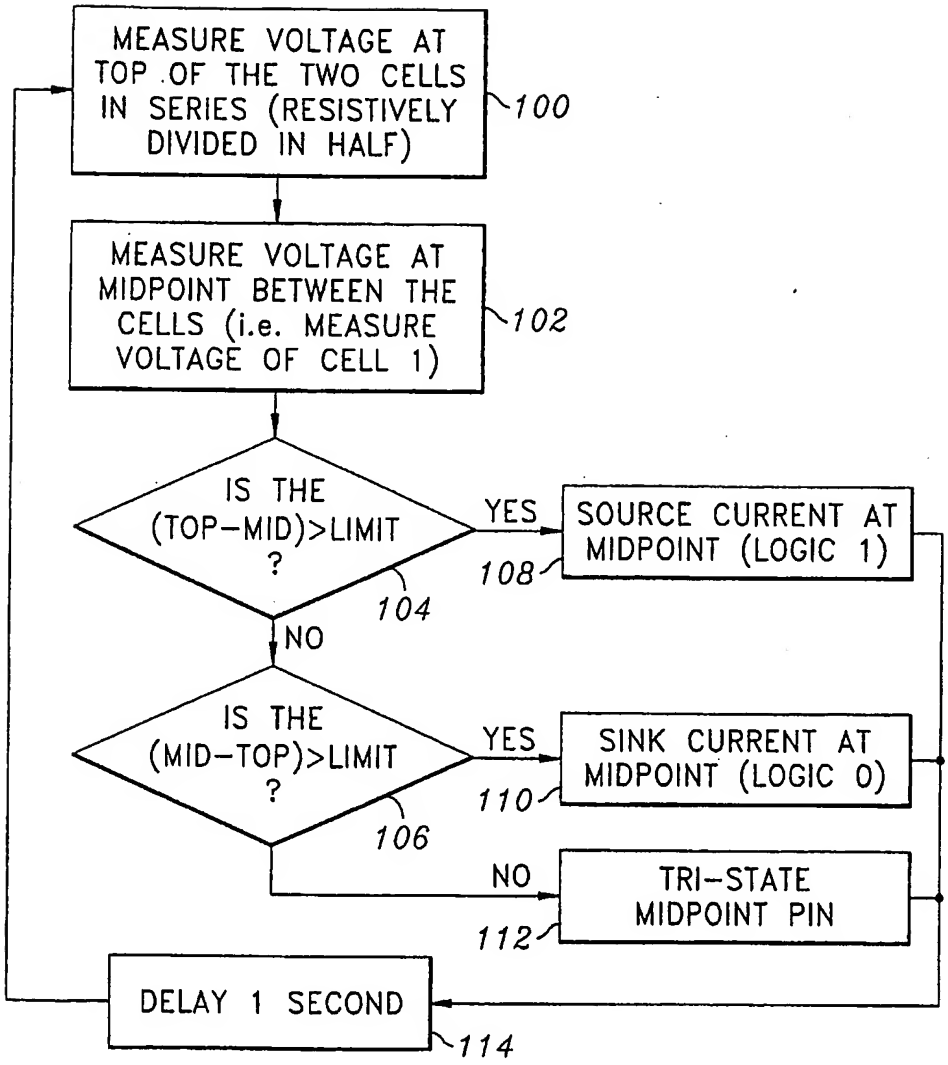
MEASURE VOLTAGE AT TOP OF THE TWO CELLS IN SERIES (RESISTIVELY DIVIDED IN HALF)
100
MEASURE VOLTAGE AT MIDPOINT BETWEEN THE CELLS (i.e. MEASURE VOLTAGE OF CELL 1)
102
IS THE (TOP−MID)>LIMIT ?
104
YES
SOURCE CURRENT AT MIDPOINT (LOGIC 1)
108
NO
IS THE (MID−TOP)>LIMIT ?
106
YES
SINK CURRENT AT MIDPOINT (LOGIC 0)
110
NO
TRI−STATE MIDPOINT PIN
112
DELAY 1 SECOND
114

FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 8976

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP 0 731 545 A (MOTOROLA) 11 September 1996 * the whole document *	1,4,9, 10,13,15 6,15	H02J7/00
Y	US 5 602 481 A (FUKUYAMA YUICHI) 11 February 1997 * the whole document *	6,15	
X	EP 0 588 615 A (SONY CORP) 23 March 1994 * the whole document *	1,10	
X	SCHMIDT H ET AL: "THE CHARGE EQUALIZER A NEW SYSTEM TO EXTEND BATTERY LIFETIME IN PHOTOVOLTAIC SYSTEMS, U.P.S. AND ELECTRIC VEHICLES" INTERNATIONAL TELECOMMUNICATIONS ENERGY CONFERENCE. (INTELEC), PARIS, SEPT. 27 - 30, 1993, vol. VOL. 2, no. CONF. 15, 27 September 1993, SOCIETE DES ELECTRICIENS ET DES ELECTRONICIENS, pages 146-151, XP000496211 * the whole document *	1,10	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H02J
X	WO 92 06525 A (BAXTER INT) 16 April 1992 * the whole document *	1,10	
X	WO 95 15604 A (ELECTRONIC POWER TECH) 8 June 1995 * the whole document *	1,10	
A	"MICROCONTROLLER-DRIVEN NICD BATTERY CHARGER" ELEKTOR ELECTRONICS, vol. 19, no. 215, 1 October 1993, pages 30-36, XP000395502	1,10	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 May 1998	Kelperis, K

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 8976

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	WO 93 10589 A (SILENT POWER GMBH) 27 May 1993 * the whole document *	1,10	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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(54) Balanced battery charger

Ausgeglichenes Batterieladegerät

Chargeur de batterie équilibré

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- **SCHMIDT H ET AL: "THE CHARGE EQUALIZER A NEW SYSTEM TO EXTEND BATTERY LIFETIME IN PHOTOVOLTAIC SYSTEMS, U.P.S. AND ELECTRIC VEHICLES" INTERNATIONAL TELECOMMUNICATIONS ENERGY CONFERENCE. (INTELEC), PARIS, SEPT. 27 - 30, 1993, vol. VOL. 2, no. CONF. 15, 27 September 1993, SOCIETE DES ELECTRICIENS ET DES ELECTRONICIENS, pages 146-151, XP000496211**
- **"MICROCONTROLLER-DRIVEN NICD BATTERY CHARGER" ELEKTOR ELECTRONICS, vol. 19, no. 215, 1 October 1993, pages 30-36, XP000395502**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to battery charging circuits and more particularly to a balanced battery charger for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another, so as to enhance the useful life thereof.

BACKGROUND OF THE INVENTION

[0002] Battery chargers for maintaining a desired charge upon one or more batteries are well known, and an example is provided by Motorola Inc. in European Patent Application No. EP 0731545. Such battery chargers are frequently utilized to maintain a charge upon a plurality of series connected batteries by applying a voltage thereacross. The series connected batteries are thereby charged according to well known principles.

[0003] However, it is also well known that such a contemporary battery charger does not mitigate the formation of an imbalanced charge upon the series connected batteries and that such an imbalance substantially reduces the useful life of the batteries. As those skilled in the art will appreciate, such imbalances commonly occur due to inherent differences in individual cell construction, such as differences in the internal resistance of each cell.

[0004] Thus, it is beneficial to provide a battery charging circuit for charging series connected batteries which prevents the formation of an imbalance between the batteries being charged, so as to enhance the useful life thereof.

SUMMARY OF THE INVENTION

[0005] The present invention specifically addresses and alleviates some of the deficiencies associated with the prior art. The invention is a balanced battery charger for maintaining a balanced charge upon a plurality of battery cells which are connected in series with one another, the balanced battery charger comprising: (a) a monitoring circuit for determining when an imbalance between the charges upon the battery cells occurs, said monitoring circuit comprising a tap for providing a cell charge signal representative of an actual charge on the selected battery cell(s); and (b) a charging/discharging circuit for selectively charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells, wherein balancing the charge upon the battery cells substantially enhances a life thereof, as disclosed in EP-A-0731545, characterised in that: (i) the monitoring circuit comprises a voltage divider for providing a reference signal representative of a desired charge on the selected battery cell (s); and (ii) the charging/discharging circuit comprises a micro controller having a comparator for comparing the reference signal with the cell charge signal and for effecting control of the charging/discharging circuit, and a multiplexed analog input and tri-state digital output port for receiving the cell charge signal and for effecting charging, discharging and maintenance of the charge upon the selected battery cell(s). The invention also provides a method for maintaining a balanced battery charge as claimed in Claim 6.

[0006] Balancing the charge upon the battery cells, in accordance with the apparatus and method of the present invention, substantially enhances the life of the battery cells.

[0007] In a preferred embodiment of the present invention a PIC16C74 micro controller is used in the charging/discharging circuit, with the monitoring circuit being defined by an analog input circuit and a multiplexed analog input and digital output circuit of the PIC16C74, and the charging/discharging circuit being defined by the multiplexed analog input and digital output circuit of the PIC16C74 micro controller.

[0008] Preferably the charging/discharging circuit is configured to charge at least one selected battery cell when the selected battery cell(s) have a lower charge than other battery cells, discharge at least one selected battery cell when the selected battery cell(s) have a higher charge than other battery cells, and maintain a charge upon at least one selected battery cell when the selected battery cell(s) have substantially the same charge as the other battery cells.

[0009] These, as well as other advantages of the present invention will be more apparent from the following description and drawings. It is understood that changes in the specific structure shown and described may be made within the scope of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a schematic of the preferred embodiment of the present invention; and

FIG. 2 is a flow chart showing the operation of the preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0011] The detailed description set forth below in connection with the appended drawings is intended as a description of the presently preferred embodiment of the invention and is not intended to represent the only form in which the present invention may be constructed or utilized. The description sets forth the functions and the sequence of steps for constructing and operating the invention in connection with the illustrated embodiment. It is to be understood, however, that the same or equiv-

alent functions and sequences may be accomplished by different embodiments that are also intended to be encompassed within the appended claims.

[0012] Referring now to FIG. 1, the balanced battery charger of the present invention generally comprises a plurality of battery cells 10 for which it is desired to maintain a balanced charge thereupon, and a micro controller 12 for facilitating the maintenance of a balanced charge upon the plurality of battery cells 10.

[0013] More particularly, the plurality of battery cells 10 comprise a first battery cell 14 and a second battery cell 16 for which it is desirable to maintain a generally uniform charge thereupon so as to enhance the useful life thereof. Although only two battery cells 14, 16 are described and shown in accordance with the preferred embodiment of the present invention, those skilled in the art will appreciate that various different plural numbers of such battery cells may be utilized according to the present invention. Indeed, each individual cell 14, 16 of the present invention may actually comprise a plurality of cells connected either in series or parallel or any combination thereof, as desired. Thus, the balanced battery charger of the present invention may be utilized to maintain a balanced or generally uniform charge upon either a plurality of single cells or various different configurations or groups of cells, as desired.

[0014] According to the preferred embodiment of the present invention, a current source 18 provides charging current to the plurality of battery cells 10 when first switch 20 is closed, thus completing the circuit to the plurality of battery cells 10. The first switch 20 is controlled via input 22 thereto which is communicated from digital output 24 of the micro controller 12.

[0015] The monitoring circuit generally comprises a voltage divider comprised of first 26 and second 28 resistors. The number and values of resistors in the voltage divider is dependant upon the number of battery cells, e.g., 14, 16, in the plurality of battery cells 10. As those skilled in the art will appreciate, the values of the resistors of the voltage divider must be selected such that the voltage measured intermediate two resistors thereof is representative of the desired charge upon the first battery cell 14.

[0016] The actual charge upon the first battery cell 14 is measured, through second switch 32 and current limiting resistor 34, at the multiplexed analog input and digital output 36 of the micro controller 12. The micro controller 12 then compares the actual value of the charge upon the first battery cell 14 which is received at the multiplexed analog input and digital output 36 with the desired charge for the first battery cell 14 as measured at the analog input 30 and generated by the voltage divider comprised of resistors 26 and 28. If the actual charge upon the first battery cell 14, as measured at the multiplexed analog input and digital output 36 is higher than the desired charge, as measured at the analog input 30, then multiplexed analog input and digital output 36 is set to a low state so as to function as a drain and thereby discharge the first battery cell 14. In a like manner, when the charge upon the first battery cell 14 determined to be at a lower than desired state when compared with the desired charge at the analog input 30, then the multiplexed analog input and digital output 36 is set at a high state, so as to function as a source and thereby effect charging of the first battery cell 14. When the charge upon the first battery cell 14 is determined to be within tolerance, i.e., generally the same as the charge upon the second battery cell 16 such that a balanced condition exists, then the multiplexed analog input and digital output 36 of the micro controller 12 is set at its zero level so as to effect maintenance of the charge upon the first battery cell 14, i.e., no charging or discharging of the first battery cell 14 occurs.

[0017] As those skilled in the art will appreciate, when only two battery cells 14, 16 are utilized, then the first 26 and second 28 resistors of the voltage divider will have equal values, e.g., 100 kohms, for example, so as to provide a signal representative of the desired value of the battery charge of the first battery 14 to the analog input 30 of the micro controller 12.

[0018] The battery charge enable signal is provided by the digital output 24 of the micro controller 12 so as to effect actuation or closing of the first switch 20 and the second switch 32. The first switch 20 is closed so as to enable charging of the plurality of battery cells 10. The second switch 32 is closed so as to effect charging of the first battery cell 14 or discharging of the first battery cell 14, as determined by the state of the multiplexed analog input and digital output 36 of the micro controller 12. The second switch 32 also prevents current leakage from the plurality of battery cells 10 through the microprocessor, when the microprocessor is unpowered. However, as those skilled in the art will appreciate, the second switch 32 may not be required if the microprocessor itself prevents such leakage.

[0019] Voltage regulator 38 regulates the voltage output of the plurality of battery cells 10 to a desired value, such as +5 volts, which may be utilized to effect the powering of desired electrical devices, including the micro controller 12, if desired.

[0020] Referring now to Figure 2, in operation the voltage is measured 100 at the top of the two cells in series and is resistively divided in half to determine the desired voltage for first battery cell 14. The voltage is also measured 102 at the midpoint between the cells so as to effect measurement of the actual voltage upon the first battery cell 14.

[0021] If the top measurement, i.e., the desired voltage for the first battery cell 14 as input to the analog input 30 minus the mid measurement, i.e., the actual measurement of the voltage upon the first battery cell 14 as measured at the multiplexed analog input and digital output 36, is greater than a predetermined limit 104, then the multiplexed analog input and digital output 36 is set 108 to a logic 1 so as to function as a current source to effect charging of the first battery cell 14. Oth-

erwise, if the mid measurement minus the top measurement is greater than the preset limit, then the multiplexed analog input and digital output 36 is set 110 to logic 0 so as to function as a drain or sink so as to effect discharging of the first battery cell 14.

[0022] Otherwise, the multiplexed analog input and digital output 36 of the micro controller 12 is set 112 to the tri-state midpoint so as to effect maintenance of the charge upon the first battery cell 14, i.e., no substantial charging or discharging occurs.

[0023] According to the preferred embodiment of the present invention, the process repeats 114 after approximately a one second delay, so as to effect repeated and continual monitoring of the balance of the charge upon the plurality of battery cells 10 and so as to effect the generally constant maintenance of a desired balanced condition thereof.

[0024] Also, although the PIC16C74 micro controller 12 utilizes a multiplexed analog input and digital output 36, those skilled in the art will appreciate that various other microprocessors may be utilized which provide for analog input and digital output on separate pins thereof.

[0025] It is understood that the exemplary balanced battery charger described herein and shown in the drawings represents only a presently preferred embodiment of the invention. Indeed, various modifications and additions may be made to such embodiment without departing from the scope of the appended claims. For example, the limits for steps 104 and 106 of FIG. 2 may be different from one another, as desired. Also, various different types and numbers of battery cells may be utilized. Further, as those skilled in the art will appreciate, various different microprocessors may be utilized. Indeed, a custom micro controller may be utilized.

[0026] Thus, these and other modifications and additions may be obvious to those skilled in the art and may be implemented to adapt the present invention for use in a variety of different applications.

Claims

1. A balanced battery charger for maintaining a balanced charge upon a plurality (10) of battery cells (14,16) which are connected in series with one another, the balanced battery charger comprising:

   a) a monitoring circuit for determining when an imbalance between the charges upon the battery cells (14,16) occurs, said monitoring circuit comprising a tap for providing a cell charge signal representative of an actual charge on the selected battery cell(s); and

   b) a charging/discharging circuit for selectively charging and discharging at least a selected one of the battery cells so as to generally balance the charge upon the battery cells (14,16), wherein balancing the charge upon the battery cells (14,16) substantially enhances a life thereof;

   characterised in that:

   (i) the monitoring circuit comprises a voltage divider (26,28) for providing a reference signal representative of a desired charge on the selected battery cell(s); and

   (ii) the charging/discharging circuit comprises a micro controller (12) having a comparator for comparing the reference signal with the cell charge signal and for effecting control of the charging/discharging circuit, and a multiplexed analog input and tri-state digital output port for receiving the cell charge signal and for effecting charging, discharging and maintenance of the charge upon the selected battery cell(s).

2. A balanced battery charger as claimed in Claim 1, wherein the monitoring circuit is configured to monitor a selected battery cell's charge relative to a charge of a plurality (10) of the battery cells (14,16).

3. A balanced battery charger as claimed in Claim 1, wherein the monitoring circuit monitors a selected battery cell's charge relative to a charge of all of the battery cells (14,16).

4. A balanced battery charger as claimed in Claim 1 wherein the charging/discharging circuit is configured to discharge at least one selected battery cell when the selected battery cell is charged higher than a desired charge.

5. A balanced battery charger as claimed in Claim 1, wherein the charging/discharging circuit is configured to:

   a) charge at least one selected battery cell when the selected battery cell(s) have a lower charge than other battery cells;

   b) discharge at least one selected battery cell when the selected battery cell(s) have a higher charge than other battery cells; and

   c) maintain a charge upon at least one selected battery cell when the selected battery cell(s) have substantially the same charge as other battery cells.

6. A method for maintaining a balanced charge upon a plurality (10) of battery cells (14,16) which are connected in series with one another, the method comprising the steps of

a) determining when an imbalance between the charges upon the battery cells (14, 16) occurs, involving obtaining, via a tap, a cell charge signal representative of an actual charge on the selected battery cell(s); and

b) selectively charging, discharging or maintaining the charge upon at least a selected one of the battery cells so as to generally balance the charge upon the battery cells (14,16), wherein balancing the charge upon the battery cells (14,16) substantially enhances a life thereof;

characterised in that the step of determining when an imbalance between the charges upon the battery cells (14,16) occurs comprises:

(i) obtaining, via a voltage divider, a reference signal representative of a desired charge on the selected battery cell(s); and
(ii) comparing the reference signal with the cell charge signal; and wherein the step of selectively charging, discharging or maintaining the charge upon at least a selected one of the battery cells comprises: using the comparison result to effect control of a charging/discharging circuit comprising a micro controller (12) having a multiplexed analog input and tri-state digital output port for receiving the cell charge signal and for effecting charging, discharging and maintenance of the charge upon the selected battery cell(s).

7. A method for maintaining a balanced charge upon a plurality (10) of battery cells (14,16) as claimed in Claim 6, wherein the step of determining when an imbalance between the charges upon the battery cells occurs comprises monitoring a selected battery cell's charge relative to a charge of a plurality (10) of the battery cells (14,16).

8. A method for maintaining a balanced charge upon a plurality (10) of battery cells (14,16) as claimed in Claim 6, wherein the step of determining when an imbalance between the charges upon the battery cells occurs comprises monitoring a selected battery cell's charge relative to a charge of all of the battery cells (14,16).

Patentansprüche

1. Ausgeglichenes Batterieladegerät zum Aufrechterhalten einer ausgeglichenen Ladung auf einer Vielzahl (10) von Batteriezellen (14, 16), die zueinander in Reihe geschaltet sind, wobei das ausgeglichene Batterieladegerät umfasst:

a) eine Überwachungsschaltung zum Bestimmen, wenn eine Unausgeglichenheit zwischen den Ladungen auf den Batteriezellen (14, 16) auftritt, wobei die Überwachungsschaltung eine Anzapfung zum Bereitstellen eines Zellenladesignals, das eine tatsächliche Ladung der gewählten Batteriezelle (Batteriezellen) darstellt, umfasst; und
b) eine Lade-/Entlade-Schaltung zum selektiven Laden und Entladen von wenigstens einer gewählten der Batteriezellen, um so allgemein die Ladung auf den Batteriezellen (14, 16) auszugleichen, wobei eine Ausgleichung der Ladung auf den Batteriezellen (14, 16) deren Lebensdauer wesentlich verlängert;

dadurch gekennzeichnet dass:

i) die Überwachungsschaltung einen Spannungsteiler (26, 28) zum Bereitstellen eines Referenzsignals, das eine gewünschte Ladung auf der(den) gewählten Batteriezelle (Batteriezellen) darstellt, umfasst; und
ii) die Lade-/Entlade-Schaltung einen Mikrocontroller (12) mit einem Vergleicher zum Vergleichen des Referenzsignals mit dem Zellenladesignal und zum Bewirken einer Steuerung der Lade-/Entlade-Schaltung, und einen multiplexierten analogen Eingang und digitalen Ausgangs-Anschluss mit drei Zuständen zum Empfangen des Zellenladesignals und zum Bewirken einer Ladung/Entladung und Aufrechterhaltung der Ladung auf der(den) gewählten Batteriezelle (Batteriezellen) umfasst.

2. Ausgeglichenes Batterieladegerät nach Anspruch 1, wobei die Überwachungsschaltung konfiguriert ist, um eine Ladung einer gewählten Batteriezelle relativ zu einer Ladung einer Vielzahl (10) der Batteriezellen (14, 16) zu überwachen.

3. Ausgeglichenes Batterieladegerät nach Anspruch 1, wobei die Überwachungsschaltung eine Ladung einer gewählten Batteriezelle relativ zu einer Ladung von allen Batteriezellen (14, 16) überwacht.

4. Ausgeglichenes Batterieladegerät nach Anspruch 1, wobei die Lade-/Entlade-Schaltung konfiguriert ist, um wenigstens eine gewählte Batteriezelle zu entladen, wenn die gewählte Batteriezelle höher als eine gewünschte Ladung geladen ist.

5. Ausgeglichenes Batterieladegerät nach Anspruch 1, wobei die Lade-/Entlade-Schaltung konfiguriert ist, um:

a) wenigstens eine gewählte Batteriezelle zu laden, wenn die gewählte Batteriezelle (die ge-

wählten Batteriezellen) eine niedrigere Ladung als andere Batteriezellen aufweist (aufweisen);

b) wenigstens eine gewählte Batteriezelle zu entladen, wenn die gewählte Batteriezelle (die gewählten Batteriezellen) eine höhere Ladung als andere Batteriezellen aufweist (aufweisen); und

c) eine Ladung auf wenigstens einer gewählten Batteriezelle aufrechtzuerhalten, wenn die gewählte Batteriezelle (die gewählten Batteriezellen) im wesentlichen die gleiche Ladung wie andere Batteriezellen aufweist (aufweisen).

6. Verfahren zum Aufrechterhalten einer ausgeglichenen Ladung auf einer Vielzahl (10) von Batteriezellen (14, 16), die in Reihe zueinander geschaltet sind, wobei das Verfahren die folgenden Schritte aufweist:

a) Bestimmen, wenn eine Unausgeglichenheit zwischen den Ladungen auf den Batteriezellen (14, 16) auftritt, was beinhaltet, dass über eine Anzapfung ein Zellenladesignal erhalten wird, das eine tatsächliche Ladung auf der gewählten Batteriezelle (auf den gewählten Batteriezellen) darstellt; und

b) selektives Laden, Entladen oder Aufrechterhalten der Ladung auf wenigstens einer gewählten der Batteriezellen, um so allgemein die Ladung auf den Batteriezellen (14, 16) auszugleichen, wobei ein Ausgleichen der Ladung auf den Batteriezellen (14, 16) deren Lebensdauer wesentlich verlängert;

dadurch gekennzeichnet, dass der Schritt zum Bestimmen, wenn ein Ungleichgewicht zwischen den Ladungen auf den Batteriezellen (14, 16) auftritt, die folgenden Schritte umfasst:

i) Ermitteln, über einen Spannungsteiler, eines Referenzsignals, das eine gewünschte Ladung auf der gewählten Batteriezelle (den gewählten Batteriezellen) darstellt; und
ii) Vergleichen des Referenzsignals mit dem Zellenladesignal;

und wobei der Schritt zum selektiven Laden, Entladen oder Aufrechterhalten der
Ladung auf wenigstens einer gewählten der Batteriezellen die folgenden Schritte umfasst: Verwenden des Vergleichsergebnisses, um eine Steuerung einer Lade-/Entlade-Schaltung zu bewirken, die einen Mikrocontroller (12) mit einem multiplexierten analogen Eingang und digitalen Ausgangsanschluss mit drei Zuständen zum Empfangen des Zellenladesignals und zum Bewirken einer Ladung, Entladung und Aufrechterhaltung der Ladung auf der gewählten Batteriezelle (auf den gewählten Batteriezellen) umfasst.

7. Verfahren zum Aufrechterhalten einer ausgeglichenen Ladung auf einer Vielzahl (10) von Batteriezellen (14, 16) nach Anspruch 6, wobei der Schritt zum Bestimmen, wenn ein Ungleichgewicht zwischen den Ladungen auf den Batteriezellen auftritt, ein Überwachen einer Ladung einer gewählten Batteriezelle relativ zu einer Ladung einer Vielzahl (10) der Batteriezellen (14, 16) umfasst.

8. Verfahren zum Aufrechterhalten einer ausgeglichenen Ladung auf einer Vielzahl (10) von Batteriezellen (14, 16) nach Anspruch 6, wobei der Schritt zum Bestimmen, wenn ein Ungleichgewicht zwischen den Ladungen auf den Batteriezellen auftritt, ein Überwachen einer Ladung einer gewählten Batteriezelle relativ zu einer Ladung von allen Batteriezellen (14, 16) umfasst.

Revendications

1. Chargeur de batterie avec fonction d'équilibrage pour maintenir une charge équilibrée sur une pluralité (10) de cellules de batterie (14, 16) qui sont connectées en série les unes aux autres, le chargeur de batterie avec fonction d'équilibrage comprenant:

a) un circuit de surveillance pour déterminer lorsqu'un déséquilibre entre les charges sur les cellules de batterie (14, 16) se produit, ledit circuit de surveillance comprenant une connexion intermédiaire pour appliquer un signal de charge de cellule représentatif d'une charge réelle sur la ou les cellules de batterie sélectionnées; et

b) un circuit de charge/décharge pour charger et décharger de façon sélective au moins l'une sélectionnée des cellules de batterie de manière à équilibrer de façon générale la charge sur les cellules de batterie (14, 16), où l'équilibre de la charge sur les cellules de batterie (14, 16) améliore de façon substantielle leur durée de vie,

caractérisé en ce que:

(i) le circuit de surveillance comprend un diviseur de tension (26, 28) pour appliquer un signal de référence représentatif d'une charge souhaitée sur la ou les cellules de batterie sélectionnées; et

(ii) le circuit de charge/décharge comprend un microcontrôleur (12) qui comporte un comparateur pour comparer le signal de référence au signal de charge de cellule et pour réaliser une commande du circuit de charge/décharge et un port d'entrée analogique multiplexée et de sortie numérique à 3 états pour recevoir le signal de charge de cellule et pour réaliser une charge, une décharge et un maintien de la charge sur la cellule ou les cellules de batterie sélectionnées.

2. Chargeur de batterie avec fonction d'équilibrage selon la revendication 1, dans lequel le circuit de surveillance est configuré pour surveiller une charge de cellule de batterie sélectionnée par rapport à une charge d'une pluralité (10) des cellules de batterie (14, 16).

3. Chargeur de batterie avec fonction d'équilibrage selon la revendication 1, dans lequel le circuit de surveillance surveille une charge de cellule de batterie sélectionnée par rapport à une charge de toutes les cellules de batterie (14, 16).

4. Chargeur de batterie avec fonction d'équilibrage selon la revendication 1, dans lequel le circuit de charge/décharge est configuré pour décharger au moins une cellule de batterie sélectionnée lorsque la cellule de batterie sélectionnée est chargée plus haut qu'une charge souhaitée.

5. Chargeur de batterie avec fonction d'équilibrage selon la revendication 1, dans lequel le circuit de charge/décharge est configuré pour:

a) charger au moins une cellule de batterie sélectionnée lorsque la ou les cellules de batterie sélectionnées présentent une charge plus basse que d'autres cellules de batterie;

b) décharger au moins une cellule de batterie sélectionnée lorsque la ou les cellules de batterie sélectionnées présentent une charge plus haute que d'autres cellules de batterie; et

c) maintenir une charge sur au moins une cellule de batterie sélectionnée lorsque la ou les cellules de batterie sélectionnées présentent sensiblement la même charge que d'autres cellules de batterie.

6. Procédé pour maintenir une charge équilibrée sur une pluralité (10) de cellules de batterie (14, 16) qui sont connectées en série les unes aux autres, le procédé comprenant les étapes de:

a) détermination de lorsqu'un déséquilibre entre les charges sur les cellules de batterie (14, 16) se produit en mettant en jeu l'obtention, via une connexion intermédiaire, d'un signal de charge de cellule qui est représentatif d'une charge réelle sur la ou les cellules de batterie sélectionnées; et

b) de façon sélective, charge, décharge ou maintien de la charge sur au moins l'une sélectionnée des cellules de batterie de manière à équilibrer de façon générale la charge sur les cellules de batterie (14, 16), dans lequel un équilibrage de la charge sur les cellules de batterie (14, 16) améliore de façon substantielle leur durée de vie,

caractérisé en ce que l'étape de détermination de lorsqu'un déséquilibre entre les charges sur les cellules de batterie (14, 16) se produit comprend:

(i) l'obtention, via un diviseur de tension, d'un signal de référence qui est représentatif d'une charge souhaitée sur la cellule ou les cellules de batterie sélectionnées; et

(ii) la comparaison du signal de référence avec le signal de charge de cellule; et dans lequel

l'étape consistant à, de façon sélective, charger, décharger ou maintenir la charge sur au moins l'une sélectionnée des cellules de batterie comprend: l'utilisation du résultat de comparaison pour effectuer une commande d'un circuit de charge/décharge comprenant un microcontrôleur (12) comportant un port d'entrée analogique multiplexée et de sortie numérique à 3 états pour recevoir le signal de charge de cellule et pour réaliser une charge, une décharge et un maintien de la charge sur la ou les cellules de batterie sélectionnées.

7. Procédé de maintien d'une charge équilibrée sur une pluralité (10) de cellules de batterie (14, 16) selon la revendication 6, dans lequel l'étape de détermination de lorsqu'un déséquilibre entre les charges sur les cellules de batterie se produit comprend la surveillance d'une charge de cellule de batterie sélectionnée par rapport à une charge d'une pluralité (10) des cellules de batterie (14, 16).

8. Procédé de maintien d'une charge équilibrée sur une pluralité (10) de cellules de batterie (14, 16) selon la revendication 6, dans lequel l'étape de détermination de lorsqu'un déséquilibre entre les charges sur les cellules de batterie se produit comprend la surveillance d'une charge de cellule de batterie sélectionnée par rapport à une charge de toutes les cellules de batterie (14, 16).

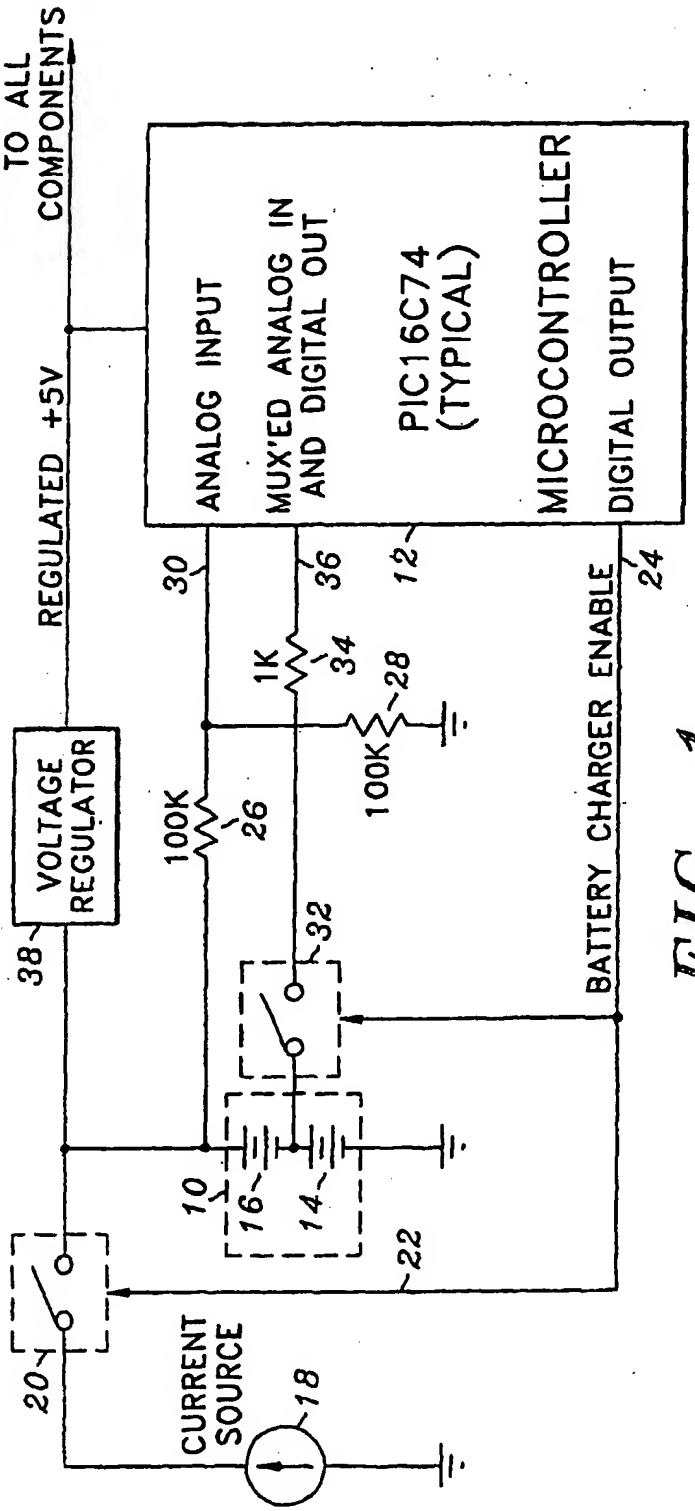
TO ALL COMPONENTS
REGULATED +5V
VOLTAGE REGULATOR
38
MICROCONTROLLER
ANALOG INPUT
MUX'ED ANALOG IN AND DIGITAL OUT
PIC16C74 (TYPICAL)
DIGITAL OUTPUT
30
36
12
24
1K
34
28
100K
26
100K
32
BATTERY CHARGER ENABLE
10
16
14
22
20
CURRENT SOURCE
18

FIG. 1

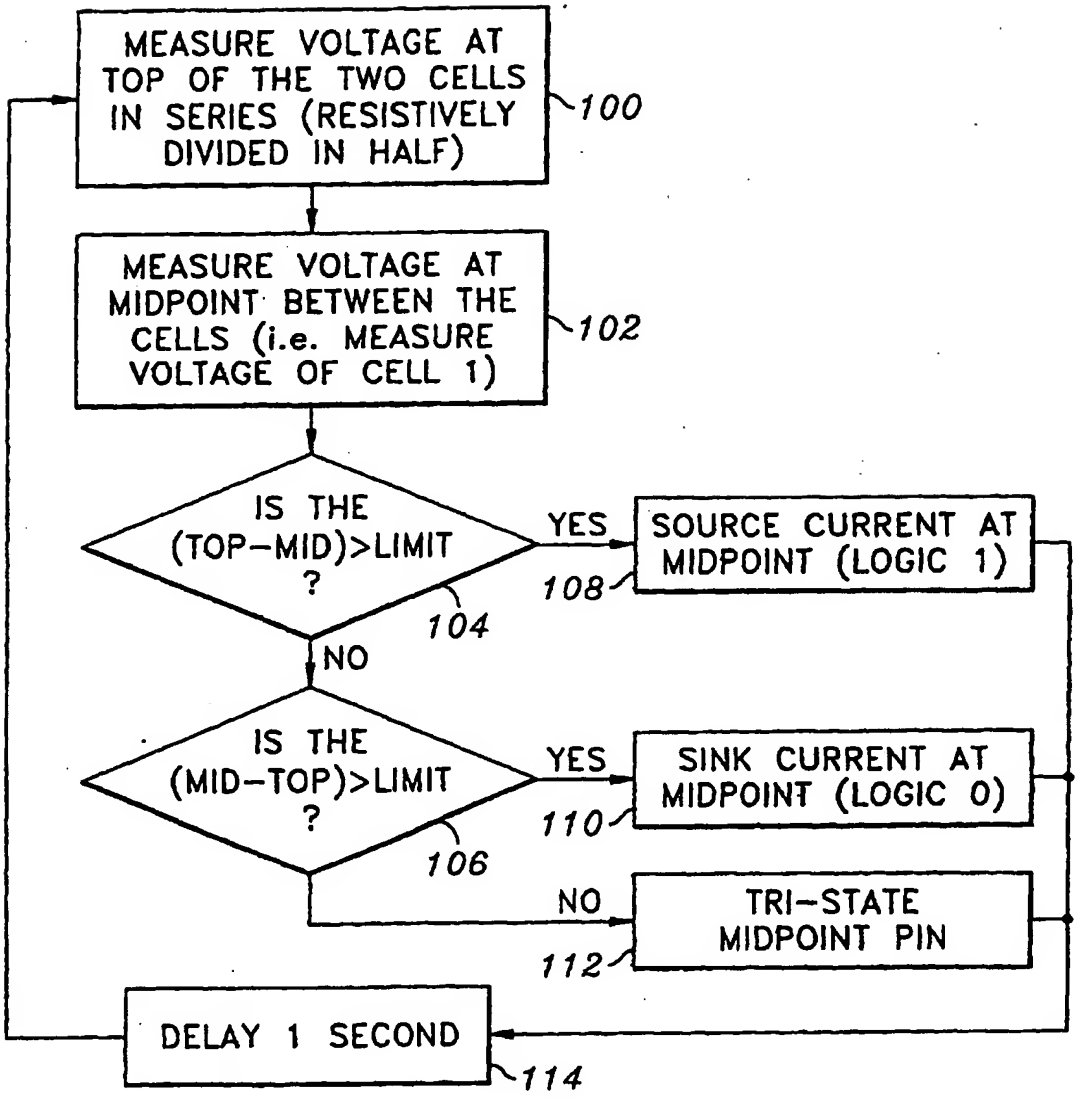
MEASURE VOLTAGE AT TOP OF THE TWO CELLS IN SERIES (RESISTIVELY DIVIDED IN HALF)
100
MEASURE VOLTAGE AT MIDPOINT BETWEEN THE CELLS (i.e. MEASURE VOLTAGE OF CELL 1)
102
IS THE (TOP−MID)>LIMIT ?
104
YES
SOURCE CURRENT AT MIDPOINT (LOGIC 1)
108
NO
IS THE (MID−TOP)>LIMIT ?
106
YES
SINK CURRENT AT MIDPOINT (LOGIC 0)
110
NO
TRI−STATE MIDPOINT PIN
112
DELAY 1 SECOND
114

FIG. 2